The Institute of Physics

BULLETIN

DECEMBER 1957 · VOL. 8 · No. 12

CONTENTS

NOTICES TO MEMBERS
Page 377

SCIENCE AND THE HUMANITIES
A. BULLOCK
Page 380

CORRESPONDENCE
Page 387

THE m.k.s.A. SYSTEM AND AMPÈRES ELECTRODYNAMICS
E. O. HERCUS
Page 388

BRANCH AND GROUP NEWS
Page 391

REVIEWS OF BOOKS
Page 395

FORTHCOMING INSTITUTE MEETINGS
Page 398

THE INSTITUTE'S JOURNALS
Page 399

INDEX TO VOLUME 8
Page 402

The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Payment of Annual Fees and Subscriptions to Periodicals for 1958

As usual the January *Bulletin* will contain a subscription reminder and a form to be returned with remittances for annual fees and subscriptions for periodicals. Members who do not pay fees by Bankers' Order are asked to make use of this form.

Bulletin format

The increase of postal charges will result in a very heavy additional cost to the Institute and steps are being taken to try to avoid or to offset a net increase. As one means of attempting to do so, the size of type used in the *Bulletin* will be slightly reduced for future issues and some other changes of format will be introduced. By this means it should be possible to publish the same amount of material as has been included in the current volume with a saving of about one-fifth of the paper used.

Recognition of College Diplomas

The Board has agreed to give full recognition to diplomas in physics to be awarded by the Welsh College of Technology, Cardiff, and Sunderland Technical College. The diplomas will be awarded to students satisfactorily completing sandwich courses and they will carry complete exemption from the Institute's academic requirements for Graduateship and corporate membership. The full list of colleges now recognized for diplomas awarded on sandwich or full-time courses is : Birmingham College of Technology ; Brunel College of Technology, Acton ; Brighton Technical College ; The Polytechnic, Regent Street, London ; Northampton Polytechnic,

London ; Northern Polytechnic, London ; Sunderland Technical College and the Welsh College of Technology, Cardiff. The whole responsibility for courses and examinations in all these colleges will lie with the colleges and the only condition imposed by the Institute is that the colleges shall appoint external examiners with powers and functions similar to those of university external examiners and selected with the approval of the Institute.

The National Council for Awards in Technology, under the chairmanship of Lord Hives, has already approved some of the above courses for the award of its Diploma in Technology, but the Institute's recognition is independent of and unaffected by decisions of the National Council. The Diploma in Technology will not carry automatic exemption from the Institute's own examinations ; exemption will be granted only when the Diploma has been obtained after a course of study in an institution specifically recognized by the Institute for this purpose.

Stimulation of Entry to the Profession

The Board has accepted the proposals of a sub-committee of the Membership and Examinations Committee that was asked to consider ways in which the Institute could try to stimulate entry to the profession. Among the proposals that have been agreed is the setting up of a committee consisting of the Honorary Officers and one representative from each of the Home Branches ; the committee will be responsible for developing means whereby information about opportunities and prospects in physics may be more widely disseminated. The following have been appointed as Branch representatives : Mr. G. C. Eltenton (*Liverpool and North Wales*), Mr. T. H. Tyler (*London and Home Counties*), Mr. R. M. Lee (*Manchester and District*), Dr. J. H. Davis (*Midland*), Dr. H. V. Walters (*North-Eastern*), Dr. J. M. A. Lenihan (*Scottish*), Dr. G. Williams (*South Wales*), Mr. K. G. Carr (*South-Western*) and Mr. W. C. Potts (*Yorkshire*).

A small committee has also been appointed to consider the development of this work in Scotland. This consists of Dr. J. M. A. Lenihan (Chairman), Professor R. V. Jones, Mr. J. R. Atkinson, Mr. H. Corteen and Mr. R. M. Sillitto.

Publication of Books

The Board has signed an agreement with Chapman and Hall Ltd., whereby future volumes in the Physics and Industry series and the Monographs for Students series will be published by the firm on behalf of the Institute. The agreement also covers other books such as conference proceedings. The selection of titles and authors and the approval of manuscripts will remain the responsibility of the Institute. An Editorial Advisory Board has been appointed to discharge these responsibilities on behalf of the Board of the Institute, with the following members : Professor F. A. Vick (*Honorary Secretary*) (Chairman), The President, The Honorary Treasurer, Professor M. R. Gavin, Dr. M. R. Hopkins, Dr. K. A. G. Mendelssohn, Dr. J. Topping, Professor J. G. Wilson.

The new arrangements will permit the Institute to increase the scope and volume of its publishing activities while making available to it the organization of a famous publishing house with connections throughout the world and especially in the United States of America.

The agreement provides for copies of books to be available to members of the Institute at privileged rates.

Books previously published for the Institute by Edward Arnold (Publishers) Ltd. will continue to be sold by that firm as will future editions of these books and any further volumes of Laboratory Notes from the *Journal of Scientific Instruments*.

Industrial Spectroscopy Group

The Board has approved a request of the Industrial Spectroscopy Group that its name shall be changed to the Applied Spectroscopy Group.

Graduateship Examination

The Graduateship examination will be held from June 2–6, 1958, in London and in such provincial centres as are required.

Annual Dinner

Members are reminded that the first Annual Dinner of the Institute is to be held at the Savoy Hotel, London, on March 26, 1958. Tickets will be available to members of all grades and their ladies.

Binding of the *Bulletin*

Members who wish to have their 1957 volume of the *Bulletin* bound are asked to send the twelve issues direct to the printers, F. J. Milner & Sons Ltd., Commerce Road, Brentford, Middlesex, as soon as possible, enclosing a sheet giving the name and address of the sender and a remittance made payable to the firm. The cost is 16s. a volume, including return postage. The binding is in red cloth with gold lettering on the front and spine.

A title page and contents list will be bound with each volume.

Title Page

The title page and contents list for the current volume has been distributed only to overseas members. Other members who would like copies should send a postcard to the Deputy Secretary but no request is needed from those who send their *Bulletins* for binding to the Institute's printers.

Physical Society Proceedings

In 1958 the Physical Society *Proceedings* will not be produced in two parts (A and B) as in the past but will be combined into one volume. The normal rate will be twelve guineas per annum and the reduced rate to Institute's members will be five guineas per annum. Members at present subscribing to these proceedings have been notified individually of the change. Renewals will not be made except on application.

Publications of the Institution of Electrical Engineers

There will be no change in the reduced rates of any of the Institution of Electrical Engineers' periodicals to Institute members in 1958. Subscriptions as taken in 1957 will be automatically renewed unless altered instructions are received. Notification of this procedure has been sent to members at present taking any of the Institution of Electrical Engineers' publications.

Science and the Humanities *

By ALAN BULLOCK, M.A.

(*Censor, St. Catherine's Society, University of Oxford*)

WHEN I was invited to give this address I conceived that there were three ways of tackling this intimidating problem. The first was to treat it philosophically and to display my ignorance, the second was to treat it historically and display my scholarship, and the third was to treat it practically. Without much hesitation, I decided in favour of treating it practically, because I supposed that this was, after all, what was wanted and I reflected that in this way I might well make a virtue of an ignorance that I could scarcely hope to conceal. I have, I am afraid, as a historian, a predisposition in favour of the concrete discussion of any question. Bishop Butler, the English philosopher, once wisely remarked : " Men first raise a dust, and then complain they cannot see." I suspect that almost any philosophical discussion which starts with two such abstractions as science (with a capital S) and humanities (with a capital H) will get no further than that question which I remember debating many times with other historians as to whether history is an art or a science, to which the answer is, it's neither, but history. So I propose, if you will allow me, to translate these semantic images, these abstractions of science and the humanities, into concrete terms, and to talk throughout my address in terms not of science and the humanities, but of scientists and humanists, and to discuss particularly the education which they receive and its effects.

The first part of my address is, in a way, the cautionary tale of an Arts Graduate. This, I would like to present to you, if you will allow me, in my own personal experience. My education consisted of three years in the Sixth Form of a Grammar School before coming to Oxford, where I spent not the usual three, but as it happened, five years in taking two Honours Schools, " Greats," the most famous of Oxford's Honours Schools, and History. To the education which I received then, I have added, since the war, twelve years as a University teacher and as the Head of a House at Oxford, which has brought me a good deal into contact with yet a third of the Art Schools of this University, with " Modern Greats," the study of Politics, Philosophy and Economics.

Now after all this, after twenty years in a University, a representative product, if I may say so, of an arts education, with perhaps more interest in the modern world and sympathy with it than some of my colleagues, I have to confess that if I had attended any of your previous lectures this week, I think it's almost certain I should not have understood a single word of the papers and discussions in which you have been engaged. That is not an exaggerated statement. In order to check it, following the best scientific and experimental methods, I went into the library and got myself out a handful of books on physics and chemistry. I sat down and I read these—or turned the pages. I found that, biology apart, I didn't understand a single paragraph of a single page of any of the six elementary text books which I had picked. Now this is, I suggest, nothing personal but a common phenomenon amongst those whose education has been in the humanities. It is not, I assure you, due to complacency on my part, or to a failure to appreciate the importance of science in the modern world. There is a sad corner of my library, overgrown with weeds by now, which contains

*An address given at the Institute Convention at Oxford, July 12, 1957.

the Penguins, the Pelicans and the Sigma books which I have collected from time to time in a vain endeavour to instruct myself in the elementary facts about science. I have a deep interest, as it happens, in the history of science though I don't know much about it, and I am so impressed by the scientists that I am in a state of open-mouthed credulity at almost any statement which they make. But once one's intellectual interests are set, while it's possible to broaden and extend them into cognate fields, I think it's almost impossible for someone trained in the humanities to bridge this gap. There are always a hundred reasons why you go on with work in your own field rather than make the appalling effort of trying to start again at the beginning and instructing yourself in the elementary truths which a scientist learns in his Fifth Form.

What are the consequences of my ignorance of science ? Again, will you forgive me if I put them in personal terms ? First of all, the intellectual consequences. It seems to me that my thinking about the subjects in which I am interested, the history of the last 150 years, contemporary politics and social change, is liable to suffer, in a number of ways of which I am quite unconscious, from the fact that I am unable to form any judgement about the most important form of social change in the modern world, namely science. I may under-estimate the importance of science, or I may over-estimate it ; I may allow too little, or I may allow too much for it. I simply cannot weigh it up because I cannot, as in the case of an historical phenomenon like nationalism or Communism analyse it, break it down, and think about it for myself.

If that be the intellectual consequence, there are other consequences. Any attempt on my part to make sense out of human experience and to ask myself the questions which, whether he admits it or not, every man asks himself—the purpose and meaning of human life—my attempt to arrive at conclusions, or even to think about those subjects, is hindered by the fact that my cosmology, my views about the physical universe, are not only pre-Einstein, but, I suspect, pre-Copernican. Intellectually I assent to the proposition that the earth revolves around the sun, but the unconscious picture that I have at the back of my mind, and which is there in so much literature, still places the earth in the centre of the universe.

Perhaps more important is the fact that such sense as I have been able to make out of human experience, the values I have inherited, the values I have discovered, and still hold to, seem to me to be in some way menaced by the existence of a large body of human knowledge from which I am excluded. I use the word " menaced " deliberately, because the unknown is always alarming, and I think that one of the reasons for the underlying suspicion and hostility of the humanist towards the scientist and particularly towards the rapid progress of science is the fear that science will destroy their traditions and values, a fear which is all the greater and the more difficult to overcome because it is fear of the unknown. I confess, for instance, that unlike Pascal, nothing so defeats my bewildered attempts to form a view of human destiny as the picture unfolded by astronomy which I am quite unable to assimilate to my ordinary thinking, and which lies like a leaden weight upon my spirits.

Finally, I come to the practical consequences of my ignorance. Insofar as I have to join in making decisions, which are bound to affect—as all national decisions may, or even university decisions—the development of science, I do so, not from prejudice (from that, at least, I hope I am free), but from ignorance of the factors which most affect our national future. Now this doesn't matter in the case of one man—and not a very important one at that, but multiplied a thousandfold, repeated in the Cabinet, in Parliament, in the Civil Service, in the Universities, the schools, newspapers and even, I suspect on the directing boards of some companies, it is an alarming prospect. It is alarming for two reasons : the first because we may very well underestimate the importance of science to our national life,

and so not devote sufficient of our national resources to its development, and important for the opposite reason—not because we may overestimate the importance of science, but because we may overestimate the infallibility of scientists and allow too much power and too much influence to them in making crucial decisions simply because we are unable to criticize the assumptions or the value of their pronouncements.

In face of this gloomy picture, and in view of my own repeated confessions of ignorance, you may well be surprised to hear me pronounce my own belief that there is no essential, no fundamental incompatibility or grounds for hostility between the study of the humanities and the study of the arts, on the one hand, and the study of science on the other hand. They pursue different aims, with different methods, different assumptions and with different results. They are as different as chalk and cheese. But the true view, I am convinced, is that each activity is not only complementary to the other, but is necessary to the other, and that when they become alienated and pursue their studies in mutual isolation, not only does general education suffer, but in the end, both science and the humanities are the poorer. I am sure this is true of the humanities where I think that the feeling of being shut out from the new worlds that the scientist is discovering has already produced a sense of frustration and loss of purpose that you can see very clearly reflected in the literature of the last twenty or thirty years. And I suspect that many scientists too are troubled in their conscience by the same problem. Indeed this, I think, is one of the hopeful signs, that there are so many of us on both sides of this artificial barrier who are oppressed by the same anxiety.

I said that I believe the division between the scientists and the humanists—the divorce between them—is not fundamental or essential. It seems to me to be due to particular historical causes, and it would be indeed a fascinating chapter in intellectual history to trace the development of this split, or if I may misapply a geological term, this fault in our civilization and culture.

We should find certain ages in which the relationship between the two great branches of human intellectual activity, between the sciences and the humanities, has been rich and fruitful, and in which each has drawn upon and stimulated the other, as in the age of the Renaissance or the age of the Scientific Revolution at the end of the 17th century. We should find throughout history certain men of great intellectual gifts who had never found any difficulty in spanning the two branches of investigation. Such, to go right back, was Aristotle, or Leonardo da Vinci, or Goethe.

We should find on the other hand, latent, often overt, hostility to the scientist as the innovator, as the man with dangerous thoughts, threatening every sort of orthodoxy, intellectual, social and religious, the experimentalist, whose attitude was summed up in a phrase which I found in a letter of Thomas Huxley to Darwin : " I will stop at no point as long as clear reasoning will carry me further."

That hostility, however, is not really due to an opposition between the humanities and the sciences ; I think it is the instinctive reaction of most societies and most individuals in face of any innovation, any threat of change, any challenge to accepted values. It has affected the innovator in the arts, in religion, the radical in politics, the experimentalist in human and social relationships, the social and educational reformer, as much as it has affected the scientist.

If we were to pursue our inquiry further, we should find one powerful theme would be the conflict between science and religion. Another, the reasons for the continued prestige of the Classics in education, and yet another—this perhaps the most important of all, the effect of the increased specialization and professionalization of knowledge, especially in the sciences, and their adoption of a cabbalistic language of their own for the communication of their findings.

But I must not be drawn into this digression, fascinating though I think it is to trace this development in intellectual history. Whatever the historical causes that have produced this present situation, it is to the

redress, or at least the amelioration of it that we have to direct our attention.

Many people, of course, believe nothing can be done about it, and not only those who have been trained in the humanities take this view. There are reactionaries among scientists, hiding their scientific toryism under the impeccable disguise of a pure science devoted only to the advancement of knowledge. But what do those of us who refuse to be defeatists have to propose ? I think that the key to it is in education. If I have little hope of doing anything about my own ignorance, I think we can do something about the generations yet to come, and for that reason, I hope you will not mind if what I have to say for the rest of this address is devoted to this question of education. I shall limit myself to the part of the problem that I know best, that is education in the universities and to some extent in the grammar schools and public schools, not because I am unaware of the importance, for instance, of the technical colleges, or of schools other than those I am going to mention, but because the time is limited, and I only know about one side. Let me divide my problem into three, saying something first of all, about scientific education, then something about education in the humanities and finally discussing the possibilities of a hybrid education.

It is clear that this country needs a great many more scientists and technologists. There is already a marked increase in the numbers taking science and mathematics in the schools, and there will soon be a consequential increase in the numbers in the universities. Whether this increase is going to be anything like sufficient for the needs of science and the nation isn't my business at this moment. I suspect it isn't. But what I want to talk about is the effect. It will, by itself, have a marked effect, of course, on the intellectual climate in the universities and in the schools. It will redress the present bias in favour of the study of the humanities. But it won't by itself, by producing more scientists, overcome the split between the humanist and the scientist unless some effort is made to break through the barrier from the side of the scientist as well as from that of the humanist. I have been perfectly frank in criticizing to you the deficiencies in my own education, but I don't believe a purely scientific education is superior to a training in the humanities. I am dissatisfied with both, like a great many other people. What I think we are after is to break through their mutual isolation. Quite apart from the new sort of mixed education, which I would like to mention at the end, I think that even the man who is going to be trained as a pure scientist—or the man who is going to follow a course overwhelmingly devoted to the humanities and the arts, should not be allowed to end his course without being exposed at some point to the influence of the other group of disciplines.

Now the training of a first class scientist, I suppose, before he takes his first job, occupies something like eight to ten years, two or three in the Sixth Form at school, three or four reading an undergraduate school in a university, and probably three as a postgraduate. I find it difficult to believe that within that period some time cannot be found to arouse a boy's interest in an appreciation of the intellectual, artistic or social possibilities outside the closed world of his own specialization, whether it's archaeology, economics, foreign languages or music. How you do it is a matter for discussion. You may try the method which Professor Vick and his colleagues have adopted at North Staffordshire: have an extra year at the university with a common course for both the sciences and the humanities. You may try the compulsory courses for scientists and technologists in the humanities which have been adopted by many American universities. I might say in passing that I would particularly urge you to consider the advantages of the social sciences, because I think this is the easiest bridge from the sciences to the humanities, and perhaps one of the most important for the scientist to cross.

But don't let us get lost in the details. Whatever method you adopt, it seems to me that there are three conditions, without which any of these experiments will be

unsuccessful. The first, and the most important of all, is the attitude of those who teach science, both at school and at the university. If they treat the notion of introducing the young scientist to anything outside the world of science as a waste of time which might be spent on valuable research, a stupid distraction from the business in hand, then it will in fact become a waste of time. The attitude of the scientists, particularly of the senior scientists, and the heads of departments, the professors, the men to whom the young scientist (even if he won't admit it), looks with some admiration, their attitude, their sympathy and enthusiasm for this, are essential, and without it no scheme, however attractive on paper, can really succeed.

My second point is that I am sure this change of attitude has got to be made from the beginning, got to be inculcated at the start, at school if possible ; certainly not later than the beginning of a boy's university career. Give a lead at that impressionable age, and the battle is half won. What is wrong, I am sure, because it is a false educational ideal, is to impose on a boy from the beginning, the idea of an intense and narrow specialization, and to urge him more and more into the closed world in which in any case he is going to spend most of his life.

My final condition is this. It is most important that the young scientist and the young art student should not live in the company of his own kind. At any good university, the students learn as much from each other as they do from the dons. That's why I attach so much importance to living in colleges and to living in halls of residence in which they will rub shoulders with and make friends among those from other faculties. I am very glad, in the plans which are now being discussed in this university for its development on the scientific side, that we should have placed high up the proposal for the foundation of a new college in which there shall be equal numbers of arts and science students.

I remember my own experience, when I was an undergraduate, of making friends in my first two years in college with many people who were studying natural and social sciences, and how it shook the complacency that had been engendered by a classical and literary education. If I come down here and bare my breast, prepared to make a fool of myself in front of this audience of scientists for a cause I believe in, it is in some measure due to the experience of those early years of my own university career.

Nothing that I have said this morning has been meant to reflect on the value of an education in the humanities. To be acquainted with literature and the arts, to be familiar with the history of the past, to have studied the organization of society, economically and politically, to have been trained in philosophical speculation, these seem to me to be among the finest and the most imperishable forms of education and I hope the day will never come when this or any other university will cease to provide them. They still offer the only general education for the man who does not want to become a professional scientist, for the scientists have not yet developed education in the sciences as a general education. If you want that, if you do not want to be a professional scientist, I think you have very largely still to turn to the general education provided by the Arts Faculties. We, for instance, in the History Faculty, never suppose that more than a tiny percentage of those we train are ever going to become professional historians. It is a general education we offer. But these traditional forms are no longer sufficient by themselves as an education for the modern world ; they have to be supplemented by some knowledge of science. How is this to be provided ? Let me first of all make a proposal which may seem very down to earth, but I think is an important one. A proposal about requirements for admission to a university. Now this, in some ways, is the key to altering the character of the syllabus in the schools. I suggest that it should be impossible in future for a boy or a girl to enter a university anywhere in this country without having a pass in the General Certificate of Education at either Ordinary

or Advanced Level in *both* a science *and* a mathematics subject. At the moment it is possible to obtain admission to Oxford at least by having a pass in *either* a mathematics *or* a science subject, with the result that people like me all read mathematics and forget about it, and none of us ever takes a science. It is most important that the potential Arts candidate should not have this opportunity to elect between mathematics and science, but should be forced to do both—and by "science" I don't mean "General Science," I mean a science which involves experimental work.

If the load at school has to be lightened, then I suggest that we should drop one of the two languages which are at present compulsory for admission to this university and in particular compulsory Latin or Greek. The minimum qualifications for a boy coming to this university would then be : English Language, French (or German or Latin—whichever one you like ; two if you can manage it, but only one *compulsory* language), Mathematics, Physics (or Chemistry or Biology) and a subject like English Literature or History.

Once he has reached the university, I believe that you will have to organize for the Arts man special courses, not in the practical training of the scientist—I doubt if that's practicable—but along the lines of the experiments that have been made in a number of universities, in such subjects as the history of science, the philosophy of science, an introduction to scientific method and the basic concepts and the current problems of at least one of the major branches of science. The aim is not to attempt to educate the Arts man in the techniques of science, the practical side of it, but to make him grasp some of the concepts, some of the language, and to persuade him of the importance of science in the modern world.

Now you must know that in saying this, I invite protests from some of my colleagues on well-known lines. They would speak of superficiality, accuse me of wishing to lower standards, of intellectual spoon-feeding and so on. They would say we are training young men to use their minds, not stuffing them with facts. Well these are fine and entirely valid arguments when it comes to the field in which a man is specializing, but, to my mind, they are less important than the plain fact and the consequences of the ignorance with which I am confronted in my own case after a much more thorough training in the humanities than most undergraduates receive. I would rather have a superficial knowledge of science than none at all. As for training people to use their minds, they cannot use their minds if they can't understand the language in which the books are written.

Finally, I think we have to go a stage further, as Cambridge is now proposing to do, and try to design a new type of mixed course which brings the sciences and the humanities together into a single syllabus on more equal terms than either of the suggestions that I have made so far ; those suggestions which have nothing novel in them are remedial suggestions. The scientist is going to be trained in science, but we would like to make sure that he is given some interest, some appreciation of a subject outside science. The humanist is going to be trained in the humanities, but we would like to make sure that he is going to have some appreciation and understanding of the importance of science in the modern world. What we have still to go after, however, is a new form of general education ; something that does not force the man who wants to have a general education to turn solely to the humanities but which will provide a course in which the two disciplines are combined to some extent in a genuine hybrid. Now Cambridge, as you know, has decided to put forward a scheme for a course divided into two parts, of which Part I, covering two years will be devoted to an Arts subject, and Part II (covering the long vacation and the third year) to a science course, the proposed subject of which would be Radioactivity and the Atomic Nucleus.

Now I admire very much the initiative that Cambridge has taken. Nothing could be more stimulating to those of us elsewhere who have been dithering about this than to see one of the great universities of the world

come forward with this proposal. But I am not at all sure myself that the best plan is that which they have hit upon, of a Part I devoted solely to the Arts, followed by a Part II, devoted solely to the Sciences. The Cambridge General Board said in its report that it considered, but finally rejected for practical reasons—mainly, I suppose, the structure of the Cambridge tripos system—the plan which I should prefer, and which I suspect the General Board at Cambridge would have preferred, for the study of arts and science subjects *concurrently*. Here, it seems to me, if Oxford can be persuaded to follow the Cambridge lead, we have a better opportunity thanks to the different structure of our courses and examination system. We already have in Oxford a tradition of mixed schools : " Greats " is a combination of the study of ancient history and ancient and modern philosophy, a curious combination that works extremely well. We have in " Modern Greats " the combined study of politics, philosophy and economics. Finally we have a third small Honours School which is a combination of any two of the subjects, psychology, philosophy and physiology. What I have in mind is something along those lines of a combined study in what we might call, for the sake of a name, Science Greats.

There might be, for example, four or six compulsory papers for everybody as the central core of the course which might bring together economics and engineering, or the social sciences and engineering, or—another possible combination that has attracted many people—physics and philosophy. Three papers would be taken on each of the two sides systematically studied, with two other papers, which would allow a choice of further subjects on whichever side a candidate wanted to place his main interest. A similar idea, I found when I was in America earlier in the year, is now being put into operation at the Massachusetts Institute of Technology, where they are proceeding with the idea of a double major.

Whatever the plan that is adopted, the aim would be the same as that at Cambridge, a new type of general education more suitable than that hitherto provided by the humanities alone. Who is it provided for ? For the man who is not going to become a professional scientist, or a professional economist, a professional scholar or schoolmaster, but for the man who is going to hold a position of administrative responsibility in the Civil Service, the Government or in Industry—in any of the many organizations which require university-trained men but which can no longer afford to recruit men whose training has been wholly in one of the sciences or one of the arts.

I cannot do better than quote to you a paragraph from the Cambridge General Board's report. " Although the Board's recommendations are based primarily on the scholarly and intellectual merits of the proposed combination of arts and science subjects, they consider that such a subject would have other secondary advantages. Those who studied it as a preparation for an administrative career, in a position where they would most probably have to deal with specialist scientists, and to make judgements on scientific matters, would be better equipped for their work through having made some study, both of the humanities and of scientific method of thought. The Board also considered there is a growing belief that the study of both types of discipline will be an advantage to some of those of the Sixth Forms at schools, but that schools find it difficult to provide for that study because there is no corresponding course at universities. The Board think that if Cambridge are to provide the kind of course they recommend, it would encourage some schools to establish corresponding combined courses in their Sixth Forms."

I am quite prepared to be told that such schemes are impracticable ; that they can only be launched after years of careful thought and preparation. All this I agree with. What don't impress me, if I may say so, are the objections in principle, the attempt to brush aside such suggestions with a display of intellectual snobbery or of academic conservatism.

Of course, we shall all die ignorant men. No system of education yet devised is going to overcome the truth which, in one of his

more sententious moments, Goethe put into the remark : " Art is long : life is short." There never will be enough time for us—or most of us—to find out what it's all about, to end up other than ignorant and bewildered. All I am asking is that the ignorance should be better distributed.

If I may sum up : the practical argument I can put in a sentence. It is a dangerous situation for any modern society which is so dependent upon, and profoundly influenced by Science, when the only people who can understand what the scientists are saying and doing are other scientists, and when the people who have so often to make decisions—national, international, government or business decisions—are constantly hampered by their inability to appreciate and criticize the scientists' arguments.

But leaving aside the practical issue, and perhaps more important in the long run, are the effects of this split on our culture. I am certain that, if it continues, it must in the end lead to a deep impoverishment, certainly of the humanities, I suspect of the sciences too. The scientist, after all, is a human being and cannot be indifferent to, or ignorant of what is happening outside the world of science. He cannot, as some in the past have wanted to do, take refuge behind the white-coated professionalism of his science, in order to avoid some of the nasty questions that are lurking outside the lab. And the great scientists have again and again been men who have been passionately engaged in human life and in human society.

As for the humanities, what more ironical situation could there be than that in which one of the greatest of human achievements—Science—an achievement which has displayed not only great intellectual, but also great moral and human qualities in its history, should be excluded from the purview of the humanist.

I believe that the most important intellectual task of our generation is to solve this problem of communication, and in some form or other to overcome, or at least to reduce, the split between science and the humanities.

Correspondence

Physical Optics

In the review of my book with this title in the November number of the *Bulletin* Dr. H. G. Kuhn says : " a fuller explanation of interference fringes of the Newton- and the Haidinger-type would have been more valuable than the inclusion of such matters as Talbot's bands or Haidinger's brushes." I write to point out that Haidinger's brushes are *not* included in the book and that there is no reference to them in the book.

R. A. Houstoun (*Fellow*).

The m.k.s.A. System and Ampère's Electrodynamics

By E. O. HERCUS, D.Sc., F.Inst.P.

(*Physics Department, University of Melbourne*)

IN HIS ARTICLE in the January *Bulletin*, Professor Lipson has issued a challenge for the production of "a field theory in which the force between two currents could be accepted as basic, in the same sense that the force between two charges or two magnetic poles is accepted as basic at present."

Though not a field theory, the major part of the answer to this challenge is to be found in Ampère's *Mémoire sur la théorie mathématique des phénomènes électrodynamiques* (1825). This remarkable paper provides a full theory of all phenomena associated with constant currents and stationary magnets, based solely on a law of force between current elements. Yet it finds no place in our textbooks, which associate Ampère's name with at least two different laws that Ampère himself did not regard as basic. In so far as the m.k.s.A system involves in some degree a return to Ampère's viewpoint, the time is opportune for a reconsideration of the elements of electricity and magnetism in the light of Ampère's discarded theory and of modern knowledge of the nature of magnetism.

POLES AND CHARGES

The law of force between magnetic poles was discovered in 1750 and that between electric charges in 1767. (Whittaker, pp. 56, 53.) From that time until quite recently these two laws have been widely regarded as an essential basis for elementary electromagnetic theory. On them, as Professor Lipson has pointed out, Faraday developed his field theory. When this method is adopted the force between two currents cannot be evaluated without field theory.

This familiar development of the subject ignores Ampère's conception of a magnet as an assembly of small current circuits, a conception now universally accepted. The analogy between charge and pole is definitely a false one, for the pole can no longer be regarded as a simple independent entity, a "magnetic molecule." It would surely be more logical to regard, with Ampère, the law of force between current elements as basic, for from it the law of force between magnetic poles can be derived.

MUTUAL FORCE BETWEEN TWO CURRENT ELEMENTS

A CHOICE OF FORMULAE

It is now known that, in the Maxwell sense, all current circuits are closed. One cannot measure experimentally the force between two current elements; at the best all one can do is to measure the force exerted on a short section of current elements by the current in a closed circuit. There is an arbitrariness in the law of force between current elements; various laws can be equally "correct" provided that they give the same result after integration for the force exerted by a closed circuit. Ampère's Law is unique in having the advantage that it satisfies Newton's Third Law; the forces are equal and opposite and in the line joining the elements. No other law satisfies this condition, and Ampère's Law is commended by Maxwell (*loc. cit.* p. 162) for this reason as "undoubtedly the best." Yet, as already stated, it finds no mention in current textbooks.

AMPÈRE'S LAW

In the period between 1820 and 1825, after he had discovered the force between two current circuits, Ampère carried out a set of four experiments, the results of which established the following principles with regard to the mutual force between current elements :

(i) the force is proportional to the product of the currents, and is not changed in magnitude but reversed in direction if either current is reversed ;

(ii) the force on a current element $i'ds'$ due to a current element ids is unchanged if ds is replaced by its rectangular components ;

(iii) The force on a current element due to a current in a closed circuit is at right angles to the element ;

(iv) The force between two current elements is inversely proportional to the square of the distance.

Ampère found that the only formula which satisfies these conditions and also Newton's Third Law is one that can be stated as follows :

If two current elements $i\,ds$, $i'ds'$ are at an angle ε to each other and are at angles β, β' respectively to the straight line of length r joining them, their mutual attraction (e.m.u.) is given by :

$$F = i\,i'ds\,ds'\,(2\cos\varepsilon - 3\cos\beta\cos\beta')/r^2 \qquad (1)$$

For m.k.s.A units a factor $\mu_0/4\pi$ or 10^{-7} must be added on the right.

Ampère chose his unit of current in such a way that two current elements ds, ds', parallel to each other ($\varepsilon = 0$), at right angles to the line joining them ($\beta = \beta' = \pi/2$), and each carrying unit current in the same sense, would attract each other with a force $ds\,ds'/r^2$ dynes. (Note that this factor is "dimensionless.") This "electrodynamic" unit must have been the first unit of current ever defined ; the electromagnetic unit introduced later is larger by a factor $\sqrt{2}$.

FORCES BETWEEN CURRENT CIRCUITS

From this basic formula, equation (1), Ampère deduced formulae for a great many standard cases. The effect of a closed circuit on a current element ds' at a given point is associated by him in the first place with a purely geometrical vector quantity, a "directrix" $\mathbf{D}$, which can be concisely expressed in vector notation (e.m.u.) by

$$\mathbf{D} = \int \frac{\mathbf{r} \times \mathbf{ds}}{r^3} \qquad (2)$$

where $\mathbf{r}$ is the distance of the element $\mathbf{ds}$ *from* the point concerned and the integral is taken round the closed circuit.

The force exerted on the current element ds' is then

$$\mathbf{F} = i\,i'\,(\mathbf{ds}' \times \mathbf{D}) \qquad (3)$$

These two formulae which occur incidentally in Ampère's work are closely allied to formulae regarded as basic in current textbook treatment. One has only to multiply both sides of (2) by i and substitute $\mathbf{H}$ for $i\mathbf{D}$, and make a similar substitution in (3) to obtain :

$$\mathbf{H} = i \int \frac{\mathbf{r} \times \mathbf{ds}}{r^3} \qquad (4)$$

$$\mathbf{F} = i'\,(\mathbf{ds}' \times \mathbf{H}) \qquad (5)$$

Formulae (4) and (5) have both been called Ampère's Law !

AMPÈRE CONCEPTION OF THIN MAGNET

Ampère regarded a thin magnet as equivalent to what he called an "electrodynamic solenoid.' This consisted of a series of small current circuits, of equal area and each carrying the same current, equally spaced along a line to which their planes were normal ; the line could be straight or curved. On applying his formula to find the force exerted by such a solenoid on a current element, he found that the force depended only on the strength and spacing of the minute current circuits and on the relative positions of the current element and the two ends of the solenoid. The free end of a solenoid of length infinite in one sense would act as an isolated magnetic pole. The mutual force between two such semi-infinite solenoids was found to be in the line joining their free ends and inversely proportional to the square of their distance. In short, Ampère was able to deduce the law of force between magnetic poles from his basic law, equation (1).

It will be seen that Ampère deduced from his one basic law the full theory of the mutual effects of constant currents and stationary magnets, without recourse to any field theory.

BIOT AND SAVART'S LAW

Soon after Oersted discovered the magnetic effect of a current, Biot and Savart (1820) published a note on the action experienced by a " molecule of magnetism austral or boreal placed at any distance from a cylindrical very fine infinite wire, made magnetic by the voltaic current." They gave the force correctly as perpendicular to the plane containing wire and magnetic pole and inversely proportional to the distance. In a footnote (p. 281) of his paper, Ampère quotes extracts from a textbook published by Biot. These show that Biot had later taught that the force exerted by a current *element* on a magnetic pole was proportional to $i\ ds \sin\theta/r^2$, or equation (4) without the integral sign. While Biot regarded this force as " elementary," Ampère points out that the equivalent integral formula (4) can be deduced from his own law of force between current elements, and states that one cannot consider as truly " elementary " a force which is manifested in the action of two elements which are not of the same nature. Yet this differential law of Biot so often appears in our textbooks with Ampère's name !

AMPÈRE'S CRITICS

GRASSMAN (1845)

The first alternative formula for the force between current elements was published by H. Grassman. According to Ampère's formula, parallel current elements at right angles to the line joining them attract each other, and two elements in the same line and same direction repel each other ($\beta = \beta' = \varepsilon = 0$ in equation (1)). There will be an intermediate position ($\varepsilon = 0$, $\beta = \beta'$, $\cos^2\ \beta = 2/3$) in which the force vanishes. Grassman regarded this as " unlikely," preferring on the ground of this intuition to sacrifice the simplicity of the balanced forces of Newton's Third Law. The Grassman formula can be expressed as follows :

$$\mathbf{F}' = i\ i'\ \mathbf{ds}' \times (\mathbf{ds} \times \mathbf{r})/r^3 \qquad (6)$$

where $\mathbf{F}'$ is the force on $\mathbf{ds}'$. This is the formula generally used in current textbooks. The force on ds is in general not equal and opposite to the force on ds' and not in the same direction. For a complete circuit the Grassman formula leads to the same result as Ampère's, but in a much less satisfactory manner. This can be illustrated by a simple example. Imagine a circuit in the form of a narrow rectangle, which can be divided into two parts A and B each containing an end of the rectangle and part of each side. The two parts may be made capable of relative motion without breaking the circuit ; for example the side parts in A may be mercury channels, while B is a wire with its side parts or arms floating in the channels. In the absence of external magnetic fields, the circuit will tend to expand, B floating away from A. In calculating the force on B there is the following contrast in the use of the two formulae :

(i) Using the Ampère formula, the force is found by integrating the force on each element of B due to each element in A.

(ii) Using the Grassman formula, one has also to allow for the unbalanced forces in B itself. The current in its arms exerts an outward force on the end, while the reciprocal forces that the end produces on the side arms are at right angles to the latter, and balance each other. B is pushed by A, but also pushes itself !

WHITTAKER (*loc. cit.* p. 86) argues from analogy :

" The weakness of Ampère's work evidently lies in the assumption that the force is directed along the line joining the two elements ; for in the analogous case of the action between two magnetic molecules, we know that the force is *not* directed along the line joining the molecules."

Why expect the force between two current elements to follow a law similar to the law of force between two minute closed current circuits ? In any case Ampère deduced the latter from the former.

One might with similar logic criticize Newton's Second Law of Motion as applied to particle motion on the ground that the end of a spinning gyroscope does not move in the direction of a force applied to it.

FIELD THEORY

The Ampère theory covers all phenomena concerned with constant currents and fixed magnets. For changing currents the forces are no longer conservative and allowance must be made for the finite velocity of light and for a varying storage of energy and momentum in the surrounding medium. I can however see no more difficulty in defining the familiar magnetic field vectors from a background of Ampère's theory than from the unit magnetic pole.

One way of doing this would be to start from the force on a current element in a magnetic field. On the older point of view the key formula is

$$\mathbf{F} = i\,\mathbf{ds} \times \mathbf{H} \qquad (7)$$

or with Sommerfeld (Zeit.f.tech.P. *16*, 420) as used by Stratton, *Electromagnetic Theory*, 1st edit., p. 242)

$$\mathbf{F} = i\,\mathbf{ds} \times \mathbf{B} \qquad (8)$$

Alternatively one may define the magnetic moment, **M**, of a small plane current circuit (again after Stratton) as the product of area by current, with direction normal to the plane, and a right-handed screw sense relative to the current. The presence of a field **B** is evidenced by a couple $\mathbf{M} \times \mathbf{B}$.

SUMMARY

There is no inherent difficulty to the development of electromagnetic field theory of Maxwell on the basis of a unit of current instead of a unit magnetic pole. This can be done, with additional advantages, if we revert to the Ampère expression for the force between current elements. It would still be possible to retain Biot's (differential) expression for the magnetic field produced by a current element, provided it were regarded as a working rule rather than a " Law," as it agrees, after integration round a closed circuit, with results established by Ampère.

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BIOT. *Annales de Chimie et de Physique* (2) **15**, 222 (1820).

GRASSMAN. *Pogg. Ann.* (3) **64**, 1 (1845).

MAXWELL. *Electricity and Magnetism*, 2nd edit., Vol. II (1881).

MOON and SPENCER. *Jour. Franklin Inst.* **257**, 203, 305 (1954).

WHITTAKER. *History of the Theories of Aether and Electricity* (1951).

The last three of these give an account of the four experiments of Ampère and the deduction from them of his Law. Apart from Ampère's paper, I have not seen any detailed account of his theory of thin magnets. An excellent account of Ampère's experiments is given in :

TRICKER. *On the teaching of electricity in schools.* John Murray (1955).

Branch & Group News

London and Home Counties Branch : Visit to the Morgan Crucible Company

On Wednesday, October 30, a group of fifty members of the Branch made a visit to the laboratories of the Morgan Crucible Co. in Battersea. The party was able to see the work of the Central Research Department, the Engineering Laboratory, and the Lighting Carbon Laboratory.

The work of the Morgan Crucible Co. has spread widely from the production of graphite crucibles, first started 101 years ago. Their present range of products includes refractories, carbon brushes and bearings, electrical resistances, furnace elements, sintered metal

bearings and components and many other important items. The methods employed for testing and producing many of these items were studied during the tour.

At the end of the afternoon, the party was entertained to tea and was able to discuss with the senior representatives of the laboratories many of the interesting things seen during the afternoon.

The Branch Chairman, Dr. J. S. Forrest, brought the visit to a close by thanking the hosts for what had been a most interesting visit.

D. T. R. DIGHTON.

Manchester and District Branch : Twenty-fifth Anniversary

Left to right : *Dr. H. Lowery, Dr. R. W. Sillars, Mrs. Sillars, Mr. O. W. Humphreys and Mrs. Humphreys.*

More than 100 members and friends attended the Conversazione arranged by the Committee of the Manchester and District Branch to celebrate the twenty-fifth anniversary of the founding of this, the Institute's first, branch. The Conversazione was held on October 23 at the Engineers' Club, Manchester. The President of the Institute and Mrs. Humphreys, and the Chairman of the Manchester Branch and Mrs. Sillars received the guests. There was a display of exhibits of scientific interest, arranged by members of the Committee and a show of scientific films selected by Dr. P. S. Henry. Among those present was Dr. H. Lowery, who was the Branch's first Honorary Secretary and to

Left to right : *Dr. Sillars with a guest, Dr. B. V. Bowden, Principal of Manchester College of Science and Technology.*

whose enthusiasm the Branch owes its existence. Other former Chairmen and Honorary Secretaries who attended were Dr. F. C. Toy and Dr. C. Sykes, both former Presidents of the Institute, Professor F. A. Vick, now the Institute's Honorary Secretary, Professor E. G. Cox and Dr. A. Hargreaves. A message of congratulation was received from Mr. W. J. Meredith, immediate past-Chairman, who was on a visit to South America. Congratulations and good wishes for the future of the Branch were expressed by Mr. Humphreys, and Dr. Sillars briefly replied.

A group examining a model of a differential analyser

Electronics Group : Conference on Transistors

A conference on transistors organized by the Electronics Group of the Institute was held at the Brunel College of Technology, Acton, on September 27 and 28, by courtesy of the Principal, Dr. J. Topping. About two hundred people attended the nine invited lectures given by government and industrial scientists. Discussion between the lectures was lively.

In the opening session (Chairman Dr. M. E. Haine) two introductory papers were presented. Mr. D. D. Jones (The General Electric Co. Ltd.) described how the characteristics of a transistor depended on such physical properties as dimensions, resistivity, mobility and carrier lifetime of the emitter, base and collector regions, and on this basis contrasted n-p-n and p-n-p structures, and compared silicon with germanium. The particular requirements for high frequency and high power devices and for operation at high ambient temperatures were discussed. Dr. W. Bardsley (Royal Radar Establishment) in his discourse on " Defects in Transistor Materials " described the various imperfections that can occur in solids, particularly germanium and silicon, and discussed in some detail the effects of impurity atoms as donors, acceptors and recombination centres. The occurrence of dislocations and methods for revealing them, together with ways in which they interact with impurity atoms and affect the electrical properties of transistor materials were also described. Mr. I. G. Cressell (Marconi-Research Laboratory) opened the afternoon session (Chairman Dr. C. A. Hogarth) with a talk on " Power Transistors." The original approach to the production of high power transistors was simply to scale up conventional low power devices and to improve the means of heat dissipation. Latterly, however, by using highly efficient

diffused emitter regions, very narrow base regions, and extreme care in the surface treatments of the devices prior to encapsulation, high powers have been achieved, exceeding 10 watts. The variation of minority carrier lifetime and surface recombination velocity with injection level and ambient conditions markedly affect the performance of power transistors. These interactions were demonstrated in terms of experimental results from the author's laboratory. Development of transistors to operate at increasingly high frequencies for both amplification and switching applications is in progress in many laboratories. Mr. J. S. Lamming (The General Electric Co. Ltd.) discussed the way in which the cut-off frequency f_a was determined almost entirely by the width of the base region, although the use of an impurity concentration gradient across the base could improve the value of f_a. A transistor developed in the author's laboratory is made by simultaneously alloying with two impurities of opposite type and then giving a short heat treatment during which " post-alloy diffusion " takes place. The result is a transistor with a very narrow graded base about 2 microns wide, f_a lying typically between 60 and 120 Mc/s. In the ensuing discussion Mr. J. R. A. Beale (Mullard Research Laboratory) described briefly a transistor made by a somewhat similar process and with a value of f_a of about 150 Mc/s. Dr. J. T. Kendall (Texas Instruments Ltd., Bedford) reviewed the methods by which silicon transistors had been manufactured and described the construction of the 40-watt transistor made by a double-diffusion process in his laboratory. Mr. J. M. Wilson (Standard Telecommunication Laboratories) in a paper with a chemical approach described the various processes that had been proposed and used for the preparation of silicon of extremely high purity. The silane decomposition process used by his firm was described and the subsequent pulling of single crystals without the use of a crucible, thereby avoiding the customary crucible contamination, enabled single crystals of " uncompensated " resistivity of order 10^3 ohm cm or higher to be grown.

In the final session (September 28, morning ; Chairman Dr. D. A. Wright) the ways in which avalanche ionization could be made to occur in semi-conductors were discussed by Dr. A. F. Gibson (Royal Radar Establishment). The use of avalanche injection at L-H junctions for the production of the negative resistance diodes developed in his laboratory was described together with an outline of a simple design theory. These have a very short switching time, but so far the forward impedance is rather high. By means of an additional injecting " trigger " electrode, a solid state analogue of a thyratron could be constructed and the characteristics of such a device were shown.

Dr. D. F. Taylor (Ferranti Ltd., Wythenshawe) discussed the conditions of alloy junction formation in silicon particularly as regards the temperature gradient through the alloy region normal to the junction during the alloying process. By suitably adjusting the magnitude and direction of this temperature gradient improved junction structures may be obtained. The final lecture on " Germanium Photo-transistors " by Dr. M. Smollett (Mullard Ltd., Southampton) consisted of an account of the mode of action of germanium photoelectric devices, stressing the differences between photo-diodes and photo-transistors, and suggesting that these devices would probably find increasing application in systems of automation.

C. A. HOGARTH.

D. A. WRIGHT.

Vol. 8, December, 1957

Reviews of Books

APPLIED PHYSICS VOLUMES 1 AND 2

By W. G. Darvell

London : English Universities Press. (Volume 1). Pp. 271. Price 12s. 6d.; (Volume 2). Pp. 246. Price 12s. 6d.

Ever since the introduction of the National Certificate courses in Applied Physics there has been some controversy as to the difference between pure and applied physics. On one hand many have maintained that there is no such subject as applied physics. The other extreme view may be illustrated by an American book[1] which consists very largely of practical details of many of the more glamorous achievements of modern technology and contains very little reference to basic principles. It is therefore with some curiosity that one approaches these two volumes which have been written for the Ordinary National Certificate course. One finds that Mr. Darvell belongs very definitely to the "no-difference" school. Volume one covers mechanics, hydrostatics and heat and volume two light, electricity and magnetism. The treatment is fairly typical of the intermediate physics courses which have been given in some technical colleges for many years. This is confirmed by the author's claim that it covers the syllabuses, not only for National Certificate courses, but also for Pharmaceutical and G.C.E. examinations. Actually the standard falls short of what is usual in a good G.C.E. Advanced Level course. It is perhaps more reasonable to judge the merits of Mr. Darvell's book in terms of its suitability for the O.N.C. course. With part-time students one cannot expect the standard to be up to a good A level in width and in depth. Mr. Darvell's course is considerably restricted in both of these respects. For example, there is no sound, and only the geometrical parts of optics are dealt with, apart from a brief section on colour. Many technical college teachers will sympathize with this curtailment though perhaps the teachers would prefer to make their own selection from a text-book with greater scope.

Mr. Darvell has attempted a simple and straightforward treatment. To some extent he has been successful within the limits he has set, though there is sometimes lack of continuity and precision. The least satisfactory section is on electricity and magnetism. Most of this is qualitative and there is insufficient emphasis on principles. The only sustained attempt at quantitative treatment is in a section on magnetostatics, oscillating magnets and magnetometers. These are dealt with in considerable detail before Ohm's Law is mentioned. Also before Ohm's Law there is an extraordinary chapter which tries to explain the various systems of electrical units although few of these are defined precisely. Much of the electricity and magnetism is outmoded. Pith balls, the Wimshurst machine, the electrophorus and terrestrial magnetism may or may not be relevant to a course for part-time industrial students. One would think that alternating current would be more appropriate. Capacitance and inductance might at least have been mentioned in a book claiming to reach G.C.E. Advanced Level.

There are still two more volumes of Mr. Darvell's book to be published. These will cover a course for the Higher National Certificate and it may be that they will remedy some of the defects mentioned above. It is recommended that they should be checked carefully for grammar, punctuation and inconsistences in abbreviations (e.g. Kgm, kg and Kg on pp. iii and 28).

M. R. GAVIN.

1. Introductory Applied Physics by Harris and Hemmerling, reviewed in *Bulletin*, September, 1955, Pp. 219.

AN INTRODUCTION TO THE CATHODE RAY OSCILLOSCOPE

London : Cleever-Hume Press Ltd. Pp. viii × 95. Price 12s. 6d.

This little book has the admirable purpose of presenting an account of the cathode ray oscilloscope together with several of its applications in a simple, non-mathematical manner for the student, apprentice or technician. On the whole, it is successful in this aim.

The accounts of the cathode ray tube, the time-base circuits, associated amplifiers and power supplies can be understood with little previous knowledge of electronics yet contain a surprising amount of practical information for so small a book. A useful section is included on pick-ups for the conversion of non-electrical phenomena into electrical magnitudes. Among the practical applications appear accounts of methods of calibration, measurement of phase relationships, measurement of component values, frequency comparison, the use of electronic switches, circular time-base applications, the testing of the regulation of watches, measurement of camera shutter speeds, flaw detection, measurements on oscillatory circuits and delineation of hysteresis loops for magnetic materials. Some brief details are given of methods of photographic recording. The remaining chapters give data on a complete range of Mullard cathode ray tubes and full details of four complete oscilloscope circuits.

The text is clearly written and illustrated though colloquial expressions are used too frequently in describing the operation of circuits, e.g. " the voltage whose frequency it is desired to ascertain." It is a pity that the text is marred by an excessive number of misprints : there are two in the preface alone !

J. YARWOOD.

INTERMEDIATE PHYSICS. Fourth Edition

By C. J. Smith

London : Edward Arnold (Publishers) Ltd. Pp. 1322 + xiii. Price 45s.

This book covers the syllabuses of the Intermediate, Advanced Level and Scholarship Examinations of the various Examining Boards. It also covers nearly all that is needed for Part I Physics of the London B.Sc. (General) Examination.

In the fourth edition of this well-established book, the author has made changes based on his own successful teaching experience and on current knowledge and opinion. For units in Magnetism and Electricity, however, he does not develop the " new system," which, " it is claimed would make the path of Knowledge easier to follow " for he, among others, does not find the system useful for teaching purposes. As in earlier editions, the treatment is mainly experimental, and, in many instances, graphical methods of dealing with experimental observations have been suggested. The number of examples has been considerably increased.

It is a comprehensive text, full of precise detail. The omnibus edition is now so large, it is somewhat difficult to use, but the work is also available in parts.

KATHLEEN E. PARKS.

A TREATISE ON PHOTOELASTICITY. Second Edition.

By E. G. Coker and L. N. G. Filon. Revised by H. T. Jessop.

London : Cambridge University Press, 1957. Pp. xxxii + 720. Price £3 10s.

The reappearance of the comprehensive volume on photoelasticity by Coker and Filon as a second edition will surely be widely acclaimed not only by current workers in the field but also by the many industrial laboratories exploring the method.

As the reviser comments " Nothing, in fact, has been published which could replace Coker and Filon as the most comprehensive and authoritative work on the theory of photoelasticity, and on the principles of its application to stress-analysis." The revised edition is substantially " Coker and Filon " and only corrections and alterations necessitated by the omission of the colour plates have been made.

The eight chapters covering as they do general optical theory, elementary theory and elasticity, the theory of artificial double-refraction, problems in a plane involving straight and circular boundaries, flexure of beams, holes and cracks, the testing of materials, and structures and machines provide the theoretical and practical background for all but the specialized worker.

H. T. Jessop provides an introduction to the volume which not only spans, in survey form, the gap between 1931 and 1957, but lists the important contributions to photo-elasticity of this period. Materials, apparatus, methods of observation and measurement and separation of the principal stresses are briefly dealt with, but the list of references cannot be regarded as complete. In dealing with the development of three-dimensional photoelasticity, H. T. Jessop considers the phenomenon of stress-freezing, materials, and methods of observation. He concludes with some remarks on other methods of observation of frozen stress and the scattered light method, before surveying the present state of photoelasticity.

The offset-litho reprinting has faithfully reproduced the quality of the original printing by the University Press, Cambridge. By replacing the colour plates by half-tone prints the original work has been recorded although the reviewer considers that the contrast in the prints could be improved.

B. SUGARMAN.

ELECTRICAL FUNDAMENTALS, VOLUME 1 OF THE SERVICES TEXTBOOK OF RADIO AND OF THE SERVICES TEXTBOOK OF ELECTRICAL ENGINEERING

By G. R. Noakes.

London : H.M. Stationery Office. Pp. 645. Price £1 10s.

This volume is intended to provide the common introduction to two separate series of books on Radio and Electrical Engineering for the use of technicians in the three armed services. The standard of the technicians varies from complete beginners to those with some considerable mathematical ability. It is interesting to see that, to cater for this wide range of technical reader, the Inter-Service Panel selected a grammar school physics master. The choice is amply justified by the result. Mr. Noakes' successful texts for A level and scholarship classes are well known. The same clarity and fluency has been adapted with considerable success to this rather more difficult task. The outcome is a clear exposition of the physical principles of electricity and magnetism, based on m.k.s. units. The subject proceeds from the electric current and electrostatics to electro-magnetism and electro-magnetic induction. This part, which constitutes almost half of the book is outstandingly successful. The remainder, which is somewhat lacking in cohesion, deals with current flow in liquids and gases, alternating currents including an introduction to three phase circuits, coupled circuits and transformers, network theory, d.c. and a.c. machines. There are also chapters on harmonic analysis, semi-conductors, illumination and measuring instruments. The book concludes, somewhat incongruously, with a separate contribution of seven pages by two other writers on materials used in radio equipment.

The principles are developed throughout by appeal to real or plausible experiments, backed by numerous clear illustrations. At its price this book is remarkably good value. It can be strongly recommended not only to the technicians for whom it was written but also to undergraduates in physics and electrical engineering. Many graduates and teachers will find much in it that is refreshing and stimulating. It is most interesting to note Mr. Noakes's confession in the preface apropos the rationalized m.k.s. system of units that " in the course of writing the book the author has been converted from a mere acceptance of its practical advantages to a wholehearted belief in it as a positive help in teaching the subject."

M. R. GAVIN.

Forthcoming Institute Meetings

Jan. 3 Liverpool and North Wales Branch

In the Department of Electrical Engineering, University of Liverpool, 7 p.m.
Tea, 6.30 p.m.

"*Radio Astronomy*"

DR. H. P. PALMER
(Jodrell Bank Experimental Station, University of Manchester)

Jan. 10 Manchester and District Branch

In the Bragg Lecture Theatre, University of Manchester, 6.45 p.m.

"*Contact Electrification*"

DR. P. S. H. HENRY, F.Inst.P.
(Shirley Institute, Manchester)

Jan. 15 London and Home Counties Branch At the Institute's House, 6 p.m.
Tea 5.30 p.m.

"*Physical Research in the Research Group of the Atomic Energy Authority*"

DR. B. F. J. SCHONLAND, F.R.S.
(Atomic Energy Research Establishment, Harwell)

Jan. 17 South-Western Branch In the Physics Department, University of Bristol, 7 p.m.

"*The General Circulation of the Atmosphere, or Why the Winds Blow*"

PROFESSOR P. A. SHEPPARD, F.Inst.P.
(Imperial College of Science and Technology, London)

Jan. 17 Non-Destructive Testing Group. At the Institute's House, 6 p.m.
Tea 5.30 p.m.

"*Some applications of Physics in Criminal Investigation*"

PROFESSOR C. B. ALLSOPP, F.Inst.P.
(Guy's Hospital Medical School, London)

This meeting will form part of a social evening and dinner to which Members' Ladies are invited.

Vol. 8, December, 1957

The Institute's Journals

PRINCIPAL CONTENTS OF THE DECEMBER, 1957, ISSUES

Journal of Scientific Instruments: Volume 34, No. 12

SPECIAL ARTICLE

Solid state image amplifiers. By Prof. G. F. J. Garlick, F.Inst.P.

Recent developments in solid state image devices using photoconductors and electroluminescent phosphors are described. The simplest device uses a thin homogeneous phosphor layer between transparent electrodes while more complex amplifiers use a combination of photoconductor and phosphor layers. By using alternating applied fields, microcrystalline photoconductors and phosphors dispersed in dielectric films may be used. The solid state amplifier offers possibilities for image conversion in the infra-red up to 6μ, in the ultra-violet and in the X-ray regions.

ORIGINAL CONTRIBUTIONS

The Hall effect compass. By I. M. Ross, E. W. Saker and N. A. C. Thompson.

Recent work on semi-conductors has led to materials in which the Hall effect in the earth's magnetic field is strong enough to form the basis of a simple electrical compass. The theory of the device is briefly presented and expressions derived for the voltage and power output, and the ultimate sensitivity obtainable. The comparative merits of various semi-conductors are shown in tabular form ; this information should be useful also for other devices based on the Hall effect.

An experimental compass unit is described, which had a power output of 6×10^{-9} W/degree of arc. Various possible systems using such a unit are briefly discussed, including the use of super-regeneration for increasing the power available.

Experiments using a simple thermal comparator for measurement of thermal conductivity, surface roughness and thickness of foils or of surface deposits. By R. W. Powell, F.Inst.P.

The thermal comparator described consists of two metal balls similarly mounted in a block of balsa wood, but one is at a slightly lower level so that it touches any surface on which the block rests. After heating to a small fixed temperature excess the block is laid in contact with the test surface. Differentially connected thermocouples attached to each ball measure the increased rate of cooling of the ball which makes contact. The differential e.m.f. is observed 10 s after contact is made and is shown to be a function of the thermal conductivity of the material on which the ball rests. When calibrated in terms of at least two substances of known thermal conductivity, determinations of thermal conductivity can be quickly made. The accuracy from single readings made on several alloys of iron, aluminium and magnesium is about ±6%, but lead departs considerably, due, it is thought, to its softness.

The condition of the surface affects the readings, so the calibration should be made for a similar surface condition. Alternatively, the device can be used as a means of measuring surface finish. Other possible uses are for measuring the thickness of surface deposits and for non-destructive sorting or identification of solid materials.

A tunable infra-red interference filter. By S. D. Smith and O. S. Heavens, F.Inst.P.

An infra-red Fabry-Pérot interferometer working at very low orders as a tunable narrow band interference filter is described. The high reflecting surfaces are provided by germanium/cryolite quarter-wave stacks and the air gap between the surfaces may be varied to change the wavelength passed by the filter. It is shown that the luminosity of such an interference monochromator may be several hundred times higher than that of a prism or grating instrument of comparable size.

The application of vacuum ultra-violet techniques to the continuous monitoring of trace concentrations of water in several gases. By W. R. S. Garton, M. S. W. Webb and P. C. Wildy.

Amethod for the determination of water in several gases is outlined in which use is made of the absorption bands of the water molecule in the 1200 Å region. A 20 Mc/s electrodeless discharge in hydrogen excites the 1216 Å Lyman α line very strongly and relatively free from neighbouring lines and bands. The radiation passes through the absorption cell, closed at both ends by lithium fluoride windows, on to the tungsten cathode of a photomultiplier which is insensitive to light of wavelength longer than 1400 Å.

An automatic adiabatic bomb calorimeter. By W. F. Raymond, R. J. Canaway, and C. E. Harris.

The paper details the conversion of an existing isothermal bomb calorimeter to an ad abatic calorimeter with automatic control. Thermistors in the inner and outer vessels are included in two arms of an a.c. Wheatstone bridge : any rise in temperature of the inner vessel above that of the outer vessel results in phase reversal of the output voltage from the bridge, which operates a gas-filled tetrode controlling a 500 W heater in the outer vessel. A second tetrode, operated by off-balance voltage, controls a 1000 W heater in the outer vessel which accommodates the initial rapid temperature rise when the bomb is fired. The equipment has been found to be more rapid and much less tedious for routine use than the usual isothermal method. Determinations of heat content take approximately thirty minutes : the coefficient of variation of a single determination, with an average temperature rise of 1·9°C, is 0·34%.

A lateral extensometer for the determination of Poisson's ratio of rock. By E. R. Leeman, and C. Grobbelaar.

A lateral extensometer is described by which the lateral strain occurring in a cylindrical rock specimen subjected to a linear axial compressive load in a compression test, can be read or recorded continuously up to the point of fracture of the specimen. The lateral extensometer has been designed to operate in conjunction with a compressometer (described in a previous article) which measures the axial strain occurring in the specimen. The measuring element used in the lateral extensometer is a linear variable differential transformer and deformations of the specimen of the order of 1 μin. can be measured. The instrument has been designed in such a way that it suffers no physical damage when the specimen, to which it is attached, fractures. In fact, over 300 rock specimens have been tested using one of these instruments without its accuracy or mechanical condition having been seriously impaired.

A water-wave measuring apparatus. By A. Brebner.

Values are given for the electronic circuit required to detect, amplify and rectify a variation in resistance produced by fairly rapidly changing water levels on a pair of immersed probes, a situation met in the measurement of water waves in laboratory experiments. The accuracy of such an apparatus is checked and assessed by comparing with the usual pointer type of gauge instead of by further electrical means and is well within the usual requirements for such experimental work.

A two-camera technique for measuring fall velocities. By R. H. Magarvey.

A photographic technique is described that affords data on several phenomena associated with freely falling drops. An essential feature of the technique is a two-camera shutter designed to obtain photographs of the falling drop at two fall distances. Velocities are calculated from a consideration of displacement and time data that appear on the photographs. Information regarding the dynamics of drop deformation is inferred from the geometry of the image pairs and the time interval between photographs. The time interval is dependent on the dimensions and speed of the shutter. The possible error in the calculated velocities of large drops is 2·5%.

British Journal of Applied Physics: Volume 8, No. 12

CONFERENCE REPORT

Summarized proceedings of the eleventh annual conference of the Stress Analysis Group—Leicester, April, 1957. By A. F. C. Brown.

The Stress Analysis Group of the Institute of Physics held a two day conference at Leicester in April, 1957, at which fifteen papers were discussed. These covered the established methods of stress analysis and some newer developments as well. Among them were three papers on fundamentals and the examination of stresses and strains on a microscopic scale. Two of these were on metals whilst the third was on rubber. An innovation was the holding of informal discussion groups on selected topics and these were agreed to have been successful.

ORIGINAL CONTRIBUTIONS

The effects of dust and force upon certain very light electrical contacts. By A. J. Maddocks, F.Inst.P., C. C. Fielding, J. H. Batchelor and A. H. Jiggins, A.Inst.P.

A study has been made of electrical contacts of platinum-gold-silver and of gold when operated at contact loadings of the order of milligrams. The general random nature of failures to make contact is demonstrated and two major causes are considered as contributing to these, dust and surface films. This paper is concerned firstly with the effects of dust and a relation between dust concentration and number of failures has been established : it appears that dust is more likely to be troublesome at very low contact loadings. The second part deals with the effects of

contact force, for the practical case of relatively uncleaned contacts, from 0–4000 μg. The work here described extends to lower contact loadings than has hitherto been reported : resistance values rise very rapidly at loads below 1 mg.

The breakdown of liquid dielectrics and its dependence on oxidation of the electrodes. By R. Hancox.

The dependence of the impulse breakdown strength of a liquid dielectric on the natural oxide layer on the electrodes used for the test is considered. It is shown that an electric field may exist in the oxide layer owing to the chemisorption of oxygen, and that this would be expected to reduce the probability of electron emission from the cathode and thus increase the recorded breakdown strength. Results are given of experiments on the breakdown of pretreated transformer oil using stainless steel, brass, and aluminium electrodes which support this conclusion.

Spectral response and linearity of photomultipliers. By H. Edels and W. A. Gambling.

The spatial variations of the spectral response of type RCA931A photomultiplier tubes have been measured by two different methods. The results, in agreement with earlier work, show that the spatial form of the response varies widely with wavelength. It is shown that for experiments utilizing only a restricted portion of the cathode surface errors up to 10% may be made in relative intensity measurements if the calibration and experimental sources do not illuminate the same portion of the cathode area. Other experiments show that the multiplier output varies linearly with input intensity for output currents up to at least 10 μA, if the electrical circuit is suitably designed.

Valve instability with cathode standing waves of cylindrical symmetry. By W. W. H. Clarke, A.Inst.P.

Experiments demonstrating the existence of preferred emission levels in thermionic valves, due to standing waves in the virtual cathode plasma, have been extended to the case of a very small circular cathode. This case is distinctive in that standing waves in the radial direction only are expected, so that a simpler pattern of preferences may be obtained, with greater spacing of preferred currents due to the small size of the cathode. Because this cathode is much smaller than those previously investigated, the change in wavelength from one supposedly boundary-satisfying standing wave pattern to the next is substantially greater. This and the (probable) absence of changes in an orthogonal standing wave structure allow significance to be attached to repeatability of the emission current preference pattern. Significant repeatability is demonstrated by experimental results, providing an important confirmation of the existence of preferred (boundary satisfying) standing wave patterns and associated preferred emission current characteristics.

Spectral sensitivity of neon discharge tubes. By T. J. Dillon, F.Inst.P.

The relative photoresponse of certain types of neon discharge tubes to irradiation at different wavelengths has been investigated by spectrophotometric methods. The experimental results, using a large number of discharge tubes, are expressed graphically as relative photoresponse for equal energy of incident radiation plotted against wavelength. The curve shows that the discharge tubes act like photoemissive cells with caesium alloy cathodes. It is suggested that the photosensitivity is due to the positive Joshi effect as well as to the presence of caesium on the tube electrodes.

Index to Volume 8

SUBJECTS

PAGE

Accounts Consolidated, The Institute 113, 114
Annual Fees, Payment of 1, 37
Annual General Meeting, Thirty-seventh 109, 249
Annual Report of the Board 139
Australian Branch Exhibition 111
Automation and Computation, British Conference 190
Board, Nominations to the... 109
Branch and Group News 29, 241, 391
Budget, The Institute's, 1957 1
Bulletin
  Contributions to 189
  Display in Libraries 1
Clock Paradox, The 210
Conferences
  Degree and Diploma Courses in Applied Physics 47, 86, 119, 166
  Electron Microscopy Group 221
  Transistors 221
Convention, Oxford 2, 37, 73, 110, 157, 249, 297, 298
Correspondence 112, 316, 344, 387
Exhibition, Australian Branch 111
Exhibition, The Physical Society 74
Finances, The Institute 111
Graduate Physicists in Industry 229
Graduateship Examination, 1957 264
Institute of Physics
  Annual Dinner 249
  Consolidated Accounts, The 113, 114
  1957 Budget 1
  Finances, The 111
  Honorary Representatives of the 2
  Journals, The 34, 70, 104, 135, 186, 218, 246, 294, 322, 346, 374, 399
  Telephone Number, The 221
Investigating the structure of the Atomic Nucleus, 1919-1956 38
Journals, The Institute 34, 70, 104, 135, 186, 218, 246, 294, 322, 346, 374, 399
Manchester and District Branch 25th anniversary 327
Meetings
  Forthcoming Institute 16, 67, 107, 138, 181, 321, 342, 369, 398
  Physical Society 12, 69, 108, 138, 309, 326, 370
m.k.s. System or The Teaching of Elementary Electricity and Magnetism, The 13, 202
m.k.s.A. System and Ampères Electrodynamics 388
Members, News of 101, 319, 367
Members, Notices to 1, 37, 73, 109, 157, 189, 221, 249, 297, 325, 349, 377
Moscow Journey 336
National Certificate Examination Papers 189
New Year's Honours List 45
News of Members 101, 319, 367
Newton's Conception of Scientific Method 350
Nominations to the Board 109
Notices to Members 1, 37, 73, 109, 157, 189, 221, 249, 297, 325, 349, 377
Organization in Applied Science Laboratories 75
Origin of Modern Science, The 250
Oxford Convention 2, 37, 73, 110, 157, 249, 297, 298
Payment of Annual Fees 1, 37
Physical Society Exhibition 74
Physics among the Sciences 300

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